Electricity Uncovers a Law of Evolution

By GEORGE ILES

Author of "Flame, Electricity, and the Camera," and "Inventors at Work."

EQUAL STEPS HAVE UNEQUAL VALUES.

On a hillside of Vermont, one stormy night in November, a lad is tramping across a league of drifting snow that buffets him at every breath, that all but blinds him. Were he to measure his paces he would find them much alike, and yet the stride that carries him over his threshold is of vastly more account than any other in his homeward trudge. Indeed, all his thousands of other steps were taken because the last stride of all would end in his passing from a northern gale to warmth and shelter. As with our homecomer on a winter night, so with a miner as he seeks copper in a ledge of distant Arizona. Hour after hour, day after day, he breaks the rock that he hopes will display a goodly vein at last. As the strokes of his pick follow one another, they have all much the same force; but it is the last blow of all, as it rings out on ore, that makes all the earlier blows worth while. Our country boy in his homeward tramp, the prospector delving through worthless limestone, both come to rewards that they have often known before. The light and comfort of his father's house are an old story to the Green Mountain boy: he has enjoyed them every winter

night of h s life. To strike a rewarding lode is a delight the miner has felt again and again in his years of hardship: its thrill has kept him steadfast in his swing of pick and shovel through many a weary month of fruitless drudgery. In both cases the end, distinctly foreseen from the beginning, cheered and lightened every moment of exertion.

A STRIDE INTO TERRITORY WHOLLY NEW.

Much more worthy of remark and celebration than repeating a familiar task for its wonted recompense, is the reaching a gift wholly new and priceless by continuing one's paces far beyond an ordinary excursion, by showering blows long after they cease in ordinary toil. Here the supreme example is the kindling of fire. At first flame was enjoyed by primitive man only in its bestowals by accident. A lightning blast setting a grove ablaze, and roasting hapless birds and brutes whose flesh was found delicious; or the welcome glow of lava streaming from a volcano, granted him boons simply golden. Flame meant comfort in winter, light between sunset and dawn, protection against wild beasts at night, the giving food a new savor and keeping quality. All these were among the earliest human wants; it may be assumed that they were among the first to be satisfied.

Fire was first struck, in all likelihood, by clashing flint against flint. This stone, widely scattered in chalk-beds, had for ages been shaped by collision into axes and hammers, chisels and arrow-heads. In striking one flint upon another to form the edge of a weapon or a tool, the stone shot out sparks, just as an old-fashioned strike-a-light does now. At a moment memorable in human fortunes, some of these sparks fell upon dried leaves, sun-cracked pith, or so eager a combustible as a cotton-boll or the catkin of an Arctic willow. A blaze was born, as many a blaze had been born before; but this time it caught the eye of a man who remembered the precious gifts that chance-fires had bestowed

upon him in past days. Doubtless as much in sheer sport as of set purpose, he repeated his clashings until he produced fire as often as he pleased. No piecemeal acquisition this, like learning to hit a mark with stone or bolt. The dexterity which led up to fire-making was gained by a succession of steps, each separated from the next by a distance scarcely perceptible; but the slight superiority in adroitness which came at last to kindling a blaze, opened in that instant a door to a whole universe of power beyond the grasp of man, however skilled, if fireless.

Sticks as well as stones were part of the store of early man. It is probable that in rubbing or grinding a bit of wood for a bow or a hammer-head, the heat of friction gave a hint for the greater heat culminating in a blaze, when the worker was muscular and persistent. A drill, commonly used to perforate hard wood, bone, or shell, to this day kindles fire beneath the hand of an Onondaga Indian.

FROM MASTERY OF FORM TO MASTERY OF SUBSTANCE.

Whatever the means by which man first created flame, that feat decided that he should be sovereign of the earth. Betwixt the temperature of the tiny blaze he first kindled and a heat just missing its intensity, there stood but a degree of the thermometric scale. And yet in bridging that inconsiderable gap the savage leaped from the province of mechanics to the empire of chemistry. In exposing a stick to fire he changed not simply its shape but its properties. Part of the wood vanished into air as it burned; another part, as charred from moment to moment, lost all cohesion, and cracked in pieces as if broken bark. In that puny flare, at the mercy of every fitful gust, lay promise of the Portland vase, the telescope of Galileo, the camera of Daguerre, the mighty engines of Watt and Stephenson, of Parsons and De Laval. There, too, gleamed prophecy of the bridges that surmount Niagara, the steel highways that weld the conti-

nents as units. Every acid and alkali, every oil and alcohol, that has ever dripped from alembic or still, was foreshown as that slender blaze flickered under its creator's palm.

All the deftness won by the savage as he had shaped oak or pine into bow or trap, flint or granite into arrow or club, had prepared him to bid flame perform old tasks in new and better ways, or grant him boons before unknown. With fire he could hollow out a log into a boat faster than with the keenest flints. When he softened copper in a blaze he could shape it with ease: when he went further and melted this copper, it took in a moment the form of a mold. With fire intensified, first by a breeze, next by the artificial blast of a rude bellows, iron ore yielded iron, and glass was created. Strangest of all, stone itself faced a rival as the tile-maker pressed his clay, and the potter turned his wheel, carrying their wares to a kiln to be baked in its fierce heat. When we remember that civilization rests on the coal mine, that steam engines aboard ship, on railroads, in mills and factories, are exerting more mechanical energy than the muscles of all mankind put together; when we see that coal-fed blast furnaces and smelteries give us the iron and steel, copper, lead, and tin, indispensable for every structural art, it is bold to ask: Could mankind impress a servant still mightier and more biddable than flame? The answer is Yes; and to-day we are in the thick of that subduing.

THE FIRE-USER IS GRADUATED AS ELECTRICIAN.

Long ago men remarked that sticks and stones were warmed when chafed together. At a later day they noticed that amber when rubbed drew to itself shreds of straw, loose silken fibres, or bits of down. As the arts of fire swept from field to field, glass had been created so as, at length, to make windows weather-proof. It furthermore bestowed lenses on defective eyes: it sharpened and broadened the gaze of astronomers, microscopists, photographers. Glass, like amber,

when rubbed attracts morsels of thread, paper, or feathers. This led, in the eighteenth century, to the invention of an electrical machine so effective that, improved in details, it survives to the present hour. Its glass disk, poised on a brass axle, is moved rapidly against a fold of silk or an India rubber comb. A few of the early machines were so large as to emit sparks long enough to resemble lightning, with which, indeed, they were identified by Franklin. His great feat may justly mark the first mile-stone in electrical progress. Let us at this point recall how much the electrician owed to fire in laying the foundation for his triumphs. His glass disk had been poured from a furnace intensely aglow; it had been annealed in an oven at first almost as hot. From smelters, forges, and foundries, all ablaze, had come the brass and iron for his framework, his tinfoil conductor, and, what is still by far the most sensitive of all detectors, his gold-leaf electroscope.

For all the amazing shock and gleam of the electrical machine, its range was narrow, and its effects were curious rather than useful. The electric pulses early disclosed their wonderful transmissibility; they could instantly traverse a thousand yards of wire and then explode gunpowder, or ring a tiny bell. But these performances were wrought by an energy trifling in volume despite its glint and crackle. Could electricity be sent forth in a fairly strong and steady stream, flowing as the water that turns a mill-wheel?

ELECTRICITY AS A STREAM.

Among the men who pondered this question was Galvani, an Italian physician. In 1759 he observed that a wire as it touched at one end the nerves of a dissected frog, and at the other end the muscles of its leg, caused a momentary twitch. When he used two wires of different metals the contractions were redoubled in vigor. He had remarked the same convulsion from the spark of an electrical machine, so he said:

"This effect is electrical." Volta, another Italian physician, took the next great step; he piled a series of disks, alternately silver and zinc, each separated from the next by cloth moistened in acidulated water. From this pile he obtained electricity as a current, instead of as a succession of irregular throbs from whirling glass. Then, and not till then, did electricity pour forth in the absence of human toil; the blaze which maintains itself from a store of fuel had found its parallel. In 1800, on the threshold of the nineteenth century, Volta greatly improved upon his pile. In each of ten porcelain cups he placed a strip of silver and a plate of zinc, bathed in an acid solution. The current now generated was fairly uniform in flow; and every voltaic cell since designed is in essence much the same apparatus. To Volta, therefore, we accord the honor of rearing the second mile-stone of electrical advance. The first, as we have seen, arose when the frictional machine was perfected, shedding sparks akin to the lightning of the sky.

NEW CHEMICAL EFFECTS AND A NEW LIGHT.

Soon after Volta's triumph, huge voltaic batteries were assembled throughout Europe, attaining great volume of current, and rising to intensities which were extreme for those early days. At first the tasks assigned them were chiefly chemical. Nicholson parted water into hydrogen and oxygen gases. Davy separated sodium from soda, and potassium from potash; electricity first fused each salt and then jostled its molecules apart into atoms. Davy passed from chemistry to illumination. He constructed a lamp into whose carbons he sent a powerful current, creating an arc of dazzling brilliancy, the parent of every similar arc since produced. Be it observed that the temperature of the Davy arc surpassed that obtainable from any fuel, giving early promise of the electrical furnaces now so important. Let us once again render an account of the debt due by the

electrician to the fire-user. Every metal plate of a voltaic cell was the child of one blaze, while another blaze furnished the glass cup and the porcelain insulator. Every brick in the furnaces, ovens, and kilns which had provided the electrical apparatus, every ounce of their cement, had taken form, had perfected its quality in flame. An obligation to fire, still more weighty, was incurred in rearing the third and final landmark of electrical conquest.

ELECTRICITY FROM FIRE

Those of us whose memories go backward forty years can recall when the voltaic cell was the sole well-spring of industrial electricity. As recently as 1870 the chief use for its currents was in telegraphy, where, as requirements were small, the cost was not burdensome. But the case was otherwise in electro-plating factories, such as those of Providence and Birmingham. So large was their demand in the wholesale deposition of metals from solutions, that there was an eager quest for cheap electricity. Early in the day that quest was successful. Electricians were soon producing current from coal, which, while twenty-fold as full of energy as zinc, was but one-twentieth part as costly. This exchange of extravagance for economy turned upon one of the most fruitful observations of all time. Oersted, in Copenhagen, in 1820, noticed that a compass needle tended to place itself across a nearby wire conveying electricity. An electric current here plainly gave rise to mechanical motion, which might execute some slight task, as winding a thread around a spool. With Oersted's discovery before him, Faraday inquired: Will electricity appear in a wire near which I rotate a magnet? He found Yes to be the answer: the current being always proportioned to the expended toil. If turning a small magnet with his hand could generate a little electricity, a powerful engine could easily spin many large magnets, and yield an enormous current. Thanks, then, to

James Watt, who had greatly improved the steam engine, motive power from fuels instead of costly zincs could now produce electricity. And Faraday's dynamo, much improved by his successors, may be driven not only by heat engines, but by winds and falling waters. At Niagara, at hundreds of cataracts less mighty, water-power long wasted is to-day generating currents for industries near and far. As populations thicken, as the radius of transmission lengthens, as the cost of fuels steadily rises, we will see the hydraulic engineer and the electrician join hands to utilize every water-power in the world, however small, if fairly constant.

Let us pause to note new items in the account which the fire-user now presents to the electrician. They include pure copper for conductors, pure iron for the cores of electromagnets, and the wide variety of steels which build boilers and engines, or are bonded together as the permanent magnets of dynamos and motors, telegraphic and telephonic instruments. By a patient study of how heat may be best converted into work, gas engines now afford in useful motion about one-third the energy-value of their fuel. This efficiency is treble that of thirty years ago, and is distinctly superior to that of any steam engine whatever.

OUR MIGHTIEST AND MOST VERSATILE SERVANT.

As heat engines grow steadily in economy, as their exhausts are utilized in warming, in drying processes, and the like, their main business becomes the production of electric currents. And for good reasons. To-day electricity does all that fire ever did, does it better, and then performs uncounted tasks far beyond the scope of flame however ingeniously employed. An electric current may be borne two hundred miles, or more, with little loss. It is convertible at a touch, and fully, into heat, mechanical impulse, or chemical stress. A crucible or an oven, thickly clad with non-conductors, may be heated by electricity with none of the

drawbacks attending fire. Combustion always pours out gases which may damage a heated mass, or oppose an intended chemical change. At Niagara Falls Mr. E. G. Acheson has devised electric furnaces of surpassing temperatures, in which carborundum and artificial graphite are cheaply manufactured. Here, as in many another case, electricity is a supplanter of fire. Quite as telling is the contrast between old methods of welding and new. In days of yore a broken propeller, a girder, or an engine shaft, had to be taken, often at great inconvenience, to a forge for repair. To-day an electric welder is taken to the ruptured parts, uniting them perfectly in a few seconds. Electricity as a source of light has grown steadily in its efficiency from the very first. The newly-devised tungsten filaments yield two-and-a-half times as much illumination as carbon threads. The flaming arcs, lineally descended from Davy's arc-lamp, are vastly more economical. The Cooper-Hewitt vapor-lamp develops a third and capital mode of producing light from electricity, sharing with the incandescent bulb the advantage of making no demand upon air, of sending forth no deleterious gases into the atmosphere.

Let us now briefly glance at the services wrought by electricity for the chemist. In former times his unions and partings were effected almost wholly by heat. To-day at Niagara Falls, and in hundreds of other industrial centres, caustic soda and a wide diversity of compounds are manufactured by electricity, not only with economy, but without the hardship and distress imposed by the use of fire. Electroplaters were at first content to deposit mere films of gold, silver, or nickel upon tableware and the like. To-day more than half the copper of the world is separated from impurities by what is virtually a plating process, cool tanks replacing the old-time smelting furnaces. This plan steadily encroaches upon the foundry blaze in reproducing plates for the printer, in building statues for the sculptor. Enlarge

such metallic deposits into immense storage batteries for power-houses, and you can equalize hours of moderate with hours of extreme demand. Batteries of the same kind, small and light, propel wagons with ideal controllability.

Other gifts as desirable are handed to mechanics and engineers. The turn of a switch sends a current into a motor, and, without belt or chain, lever or pulley, furnishes a swift and uniform drive, free from heat, odor, and vibration. Powerful motors of this kind are making travel quicker, safer, and pleasanter than steam locomotion ever was. From the very first the Morse telegraph promised all this in signals due to the long-distance transmission of electricity as motive power. Telegraphy, one of the prime services of the electrician, is to-day supplemented, and in wide areas supplanted, by the telephone. That simplest and most useful of all electrical devices may span two hundred miles, with no other linkage than the ether of space. That ether has the obliging quality of carrying its Marconi pulses in curves around the world, whereas light-waves run in straight lines, and hence are narrowly limited in their play as signals. Greatly does the mariner rejoice as he finds his wireless messages take wing better in darkness, or fog, than in sunshine or clear weather.

ELECTRICITY AS A REVEALER.

Electricity lights the lamp of research, the while it presents energy in its most useful and biddable phase to every practical art. Sir William Crookes, Sir Joseph Thomson, and Professor Ernest Rutherford, using a nearly empty bulb of glass, strongly electrified, have broken down its gaseous contents into corpuscles which they call electrons. They aver that electrons bearing positive electricity are comparable with a hydrogen atom in dimensions, that those carrying negative electricity are but one-thousandth this size. These electrons, whether derived from iron, copper, or other chemi-

cal " element," are alike. Fire gave the chemist command of molecules and their constituent atoms; electricity empowers him to resolve the atom itself into what may be the ultimate units of nature. Twenty years ago we called a pine board opaque. To-day the rays from a negative electrical pole dart through the wood almost as readily as sunshine through a window pane. So do rays from thorium, uranium, and radium; some of these projections consist in material particles, so that they wholly differ from ethereal waves of common light.

These, and equally novel kinds of radiation, have, within the past ten years, disclosed themselves to the electrician. Here an indispensable aid is an electroscope — little more than two leaves of gold-foil, brought to divergence or approach by like or unlike polarities. Examined by this device, radium uncovers a most complex structure, yielding emanations of highly contrasted qualities. Yet more: the interatomic gyrations of radium are estimated as far surpassing the most intense chemical energy. It is computed that an ounce of radium, were its internal motion fully utilized, could lift ten thousand tons a mile from the earth. It is believed that hydrogen and other elements contain a like wealth of motion. What thus far remains hidden is a means of tapping these stupendous reservoirs of power.

It nas long been surmised that the more complex elements of chemistry have been evolved from the simpler. Recent investigations support this view. Sir James Dewar has produced helium from radium; Professor Frederick Soddy has derived helium from uranium. Uranium is deemed to be the parent of radium; and radium, when its transformations are at an end, is believed to terminate its career as lead. Not only does the "atom" thus appear to be divisible, but the "elements" themselves are held to be transmutable, so that the ancient creed of alchemy is revived. As a corpuscle rushes along, at a speed approaching that of light, its inertia

increases with its velocity, as if its mass entangled itself with units still more refined. Indeed, among physicists the opinion gains ground that matter is only a series of knots tied in the ether, matter and ether forming a continuous whole. Surely it is a new heaven and a new earth that the electric ray thus reveals, utterly transcending phases of matter and motion which our fathers, in the age of mere fire, were wont to regard as ultimate.

And let us remember that it is because the wealth of nature rests in mines successively deeper and richer, that the possibility has lain of these advances, epoch after epoch, in human faculty. Had our planet been destitute of trees or coal, peat or petroleum, there could have arisen no fire-kindler with his progeny of potters and brickmakers, blacksmiths and chemists. Coal could lift itself thirty miles from the earth were its latent energy fully called forth. This is why Watt, Fulton, and Stephenson could devise engines which, though wasteful, have transformed the face of the earth. Had our globe lacked metals, where would electricians have found magnets and conductors, tinfoil for condensers, gold-leaf for electroscopes? Abounding treasure in materials, turned to account by discoverers and inventors ever keener and bolder, have brought mankind at last from a mastery of form to a mastery of substances, from a knowledge of atoms and molecules to a command of nature's inmost heart.

CULMINATION AND TRANSCENDENCE.

We usually think of evolution as due to slow gains in strength, swiftness, or vision, because this is its ordinary course. From this steady-going advance, in which one step counts for no more than another, we should see no departure were nature but one kingdom, disposed in an unvarying level. But nature has many diverse planes of life and action, and between these are frontiers across which a single bound may carry a bold and sagacious pioneer. Then, in an

instant, he enters upon resources so rich and manifold that he finds himself in an empire, beside which the field of his earlier days sinks to the rank of a mere province. When skill of hand rose to the kindling of fire, mankind then and there sprang from a realm shared by beast and bird, to a sphere infinitely more wide and lofty. To ability in bestowing form was now joined power to change not forms simply, but substances themselves. The craftsman seized the transforming wand of the chemist. Every day he uncovered new and golden qualities in long familiar sand and clay, wood and metal. Thanks to tools and weapons born of fire, he became so acute an observer, so original an inventor, that at length he strode across another boundary, and subdued that subtler kind of fire, electricity.

Development from monad to man may have been due to a long series of steps, each short and halting. But incalculable was the impetus due to a few epoch-making strides. One of them swept man over the barrier between the fire-kindler and his fireless parents. Another divided Volta from brother-physicians who gazed idly at the lightning of the sky. Earlier far than Volta was that distant forefather of his who, probably in sheer fun, first prophesied human speech. There was doubtless a long period during which the ancestors of man, in common with other animals, could utter only cries of rage, of fear, or other emotion. One day, let us suppose, the growl of a tiger, the chirp of a bird, w mimicked, and a new kind of communication began. In th moment human language may have taken its rise. Words, as we use them to-day, express joy or dread, hatred or love, as plainly as do inarticulate cries. But words stand for much else: for all persons, all things, the abstractions of philosophers, the images of poets.

Mimics of sound had brethren who were mimics of form, and who thus rendered another supreme service to their kind. Prehistoric man scratched on bone the outlines of deer and

horses, elephants and men. When, at a much later day, the simplified figure of an owl stood for the "Mu" sound which named an owl, the letter "M" was born into an alphabet. With the art of writing, slowly acquired and perfected, it became easy to record and transmit knowledge long after its discoverer and his scribe had passed away. Thus simply did man-in-the-making enter upon the faculty of language, with distinct promise that in due season his children should indite history and poetry, that their voices, in recognized tones, should be heard across the Andes and the Alps.

The argument here briefly sketched, and brought to date, was developed by the present writer in "Flame, Electricity, and the Camera," in 1900. This work is published by Doubleday, Page & Co., 133 East 16th Street, New York. Two dollars.

Montreal, Canada, July, 1909.

Inventors at Work

With Chapters on Discovery

By GEORGE ILES

Edison tells how he invented the phonograph. Bell, how he sent a message along a sunbeam. Bessemer, how he produced his famous steel. Other feats, as striking, are recited in every field of engineering and machine design. The uses of compressed air, of reinforced concrete, and the latest economies in heat-engines, are described and pictured.

What gives the book unique value is its setting forth the PRINCIPLES of discovery and invention. The economy of FORM is, for example, explained and illustrated in a diversity of rails and girders, trusses, arches, and bridges. Next comes a full discussion of how materials are chosen for their strength, elasticity, or other qualities; and the modes in which properties are bettered, as in alloying iron with carbon. How dimensions and properties are measured with accuracy is shown, with remarks on the interchangeability of parts which has grown out of their precise multiplication. Then follow chapters on Nature's Hints to Inventors, Observation, Experiment, Automaticity, Simplification, and Theorizing.

Profusely illustrated. Many portraits. 503 pages. $2.50. Postage, 25 cents.

DOUBLEDAY, PAGE & CO.
133 East 16th Street,
NEW YORK